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Use of Power Driven Soil Resistance Recorder for Study of Compaction of Soils by Tractors

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Use of Power-Driven Soil Resistance Recorder for Study of Compacting of Soils by Tractors

Soil packing produced by tractor wheels or tracks has been a topic of discussion since the advent of the tractor and nearly every new type of wheel tread and track developed has been the subject of various claims of greater traction with less packing. Most of these claims have been unchallenged as no satisfactory and easily applied method had been developed for measuring the relative compaction of the soil. The methods of determining the volume weights for layers of soil under the track, of the soil fixation used by Misenko (1) and of driving piles used by Heath (2) should give accurate data but all are slow and laborious. Culpin (3) tried shooting lead bullets into the soil. One recently developed device is designed to measure the penetration of a tapered rod when dropped from a predetermined height and other units have been designed to push a probe into the soil with a fixed force. All of these methods use the depth of penetration as an index of compactness and are apparently unduly affected by hard layers in the soil. They give a composite value to the depth of pentration but do not indicate the condition that might go to make up this result and give no indication of conditions below. Culpin (3) developed an apparatus for forcing a probe into the soil at a nearly constant rate to any desired depth. The probe is forced down by calibrated springs whose deflections are recorded on a strip chart, thus giving an indicator type chart for each test. This unit is light in weight, easily operated and produces very satisfactory measurements but has the disadvantage that the movement of the probe is retarded by the amount the springs

are extended. This may cause considerable variation in the speed of penetration when hard or soft layers are encountered.

The soil resistance recorder shown in figure 1 was developed at the Tillage Machinery Laboratory. It operates on the same principle as the device developed by Culpin, but is driven by an electric motor instead of by hand, uses a hydraulic unit for recording the pressures and the length of chart is the same as the depth of test. It is heavier in weight but this is not a disadvantage when used at the laboratory as it is mounted on the power car as shown in figure 2. A field unit would necessarily be mounted on transport wheels. The probe is forced into the ground at approximately $\frac{1}{8}$-inch per second by the electric motor driven worm. A hydraulic cell is located between the guide arrangement on the lower end of the worm and the probe so that the force is transmitted through it. The pressures created are recorded on the chart to the left of the probe by means of a helical spring pen mounting. This arrangement is mounted rigidly on the probe guides so that the distance corrected for the arc of the pen arm of any point below the base line is the same as the depth of the probe. The probe consists of a $\frac{3}{8}$-inch diameter rod with a $\frac{1}{2}$-inch diameter head attached to the lower end. Cupped, conical, rounded, and flat heads were tried. Since there were no significant differences in the resistance to the different types, the flat head was used for all tests. Culpin (3) shows that the speed at which the probe is forced into the soil affects the resistance in a complicated relationship that may be similar to that for plows, etc. This variable is eliminated for this study by using one speed for all tests.

In studying the data obtained with any type of unit that measures the soil condition by its resistance to penetration, a true measure of conditions is not indicated until a uniform layer of soil is encountered. Thus if the lug equipment compacts the soil behind the lugs, then breaks this area loose to form a compacted clod, the compactness of this clod is not measured. This could probably be done only by careful apparent specific gravity determination for these clods. The data obtained with the resistance recorder indicates the packing effects produced in the area below that loosened by the lug equipment.

Test Procedure

The soil used for each test was prepared as uniformly as possible by subsoiling to a depth of 11 to 12 inches, applying moisture if needed, compacting very slightly, then leveling. The conditions used were comparable to those encountered in plowed fields, except that the soil was loosened to a greater depth. The tractor to be used was hitched to the "power car" through the dynamometer so as to tow this car for load, figure 3. The desired loads were applied by using the brakes on the car. A pressure gage in the oil line between the dynamometer and recorder on the power car enabled the man operating the brakes to keep the load constant. The impressions produced in the Davidson Loom by the rubber tires and crawler are shown in figure 4. Speeds for all tests were obtained from the dynamometer chart, and the tractor used to compare the effects of rubber tires and steel lugs was equipped with a device for recording the revolutions of the drive wheels for determining slippage. The slippage data shown in figures 5 and 6 were obtained from counts of the revolutions for the wheels and tracks over

a measured distance. Revolutions of the wheels or tracks over the same soil conditions with no load on the tractor were used as a base.

The soil resistance recorder was located over the center of the impression made by the wheel or track and data taken by running the probe to depth of 12 to 16 inches. Readings were taken on the center line of the impression and, by increments of 3 inches to 15 inches on either side. Duplicate readings were taken whenever possible and the data for the two sides of the impression were averaged.

Discussion of Tests and Data

Two series of tests were made. One series compares the packing of the soil, measured by restance to a ½-inch probe, produced by a general prupose tractor equipped wih steel tires, and 4-inch spade lugs and with 10.00x36" pneumatic tires. Curves showing the soil resistance under the wheel impressions are shown in figures 5 and 6. The other series compares the packing by two tractors of approximately the same weight, one equipped with 9 x 24-inch pneumatic tires and the other equipped with 6-inch by 50-inch (ground contact measurements) tracks with 1¼-inch cleats. The data for these tests are shown in figures 7 and 8. The soil type, drawbar loads, speed and per cent slip for each condition are shown in the figures. Table 1 shows the analysis of the three soils in which these tests were made.

The data in figures 5 to 8 are the restance to the ½-inch diamter probe on a plane 5 to 8 inches below the surface of the undisturbed soil. The depth varied with the condition of the soil and was established for each series of tests so that it was just below the loosening effect of the deepest lug equipment. Various methods of presenting the data,

including the plotting of isodensity diagrams and the averaging of the measured resistances to certain depths, were tried but the method used here appeared to give the most representative picture of what took place.

Both the steel lug and rubber tire equipment increased the resistance of the soil to penetration by the probe to the entire depth of subsoiling on the plots (12 inches) whereas the effect for the track unit tapered off at 8 to 10 inches for the conditions of these tests. It was noted in all tests that the rubber tires formed a more compact layer of soil immediately below the lugs than was formed under comparable conditions by either the steel lug or track equipment. The resistance data show that the relationship between the packing effects produced by the rubber tires and tracks continued for a range of 3 or 4 inches below the depth to which the lugs on the rubber tires penetrate. They show also that the packing effect as measured by the resistance to penetration for steel lug and rubber tire equipment were approximately equal for the area below the highly compacted area produced by the rubber tire. All types of traction units caused compression of the soil as much as 12 to 15 inches to either side of the center line of the impression at the depths shown. These data check closely with the theoretical results expressed mathematically by Doner (4).

Conclusions

A power-driven soil resistance recorder is described and preliminary data obtained with it are shown. These data indicate that all types of traction units pack the soil to a considerable depth and that this packing effect is vectored out appreciable distances beyond the edge of

the tread impression. It is indicated also that rubber tires tend to set up a more compact layer of soil than that formed by either steel lug equipment or tracks.

Table 1

ANALYSIS OF SOILS

Soil	Sand	Silt	Clay	% Organic Matter	SiO_2/R_2O_3	pH
Davidson Loam*	72.8	3.38	23.82	1.18	1.43	5.32
Davidson Clay	30.0	16.6	53.4	1.62	1.05	5.14
Decatur Clay	28.1	31.3	40.6	0.98	1.67	5.75

* This soil is actually a loamy sand but is referred to as loam for convenience in presentation.

Literature Cited

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3. Culpin, Claude - Studies of The Relation Between Cultivation Implements, Soil Structure, and The Crop. The Journal of Agricultural Science, Vol. 24, part 1, Jan. 1936.

4. Doner, Ralph D. - A Theory of Arch Action in Granular Media, Agricultural Engineering, Vol. 17, No. 7, July 1936.

Note: Pages 6, 7, and 8 consolidated.

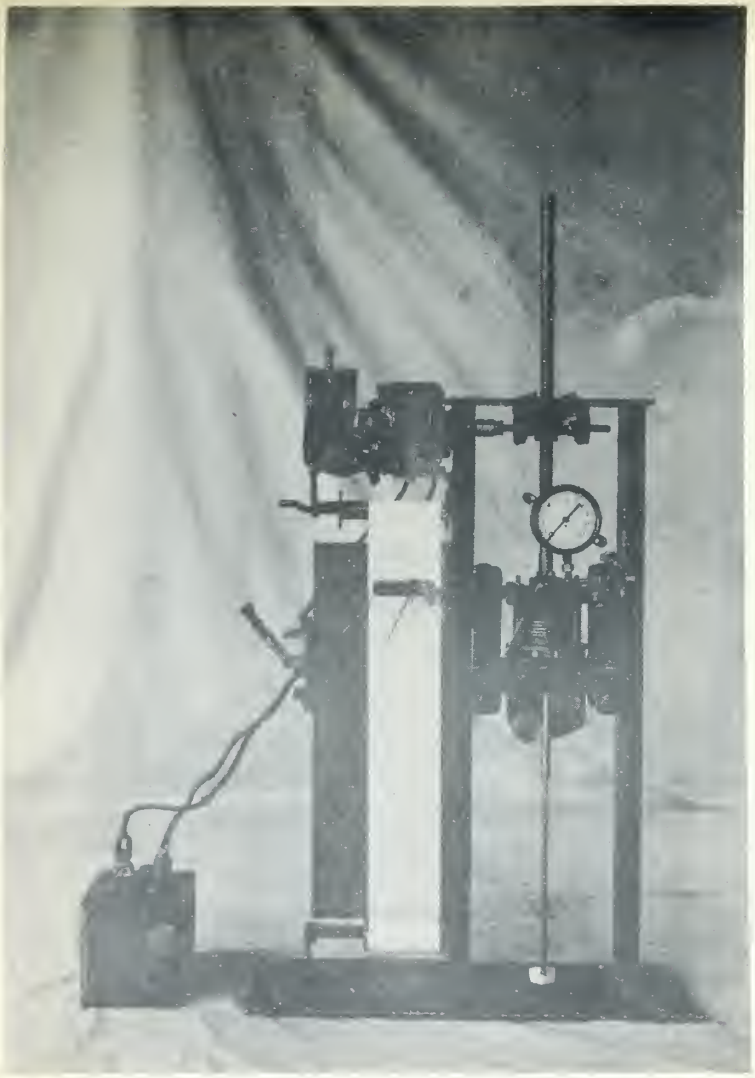

Fig. 1

The Power-Driven Soil Resistance Recorder Showing Drive and Guide Mechanisms, Probe, Indicating Gage, Recording Pen, and Test Chart.

Fig. 2

The Power-Driven Soil Resistance Recorder Mounted on Power Car.

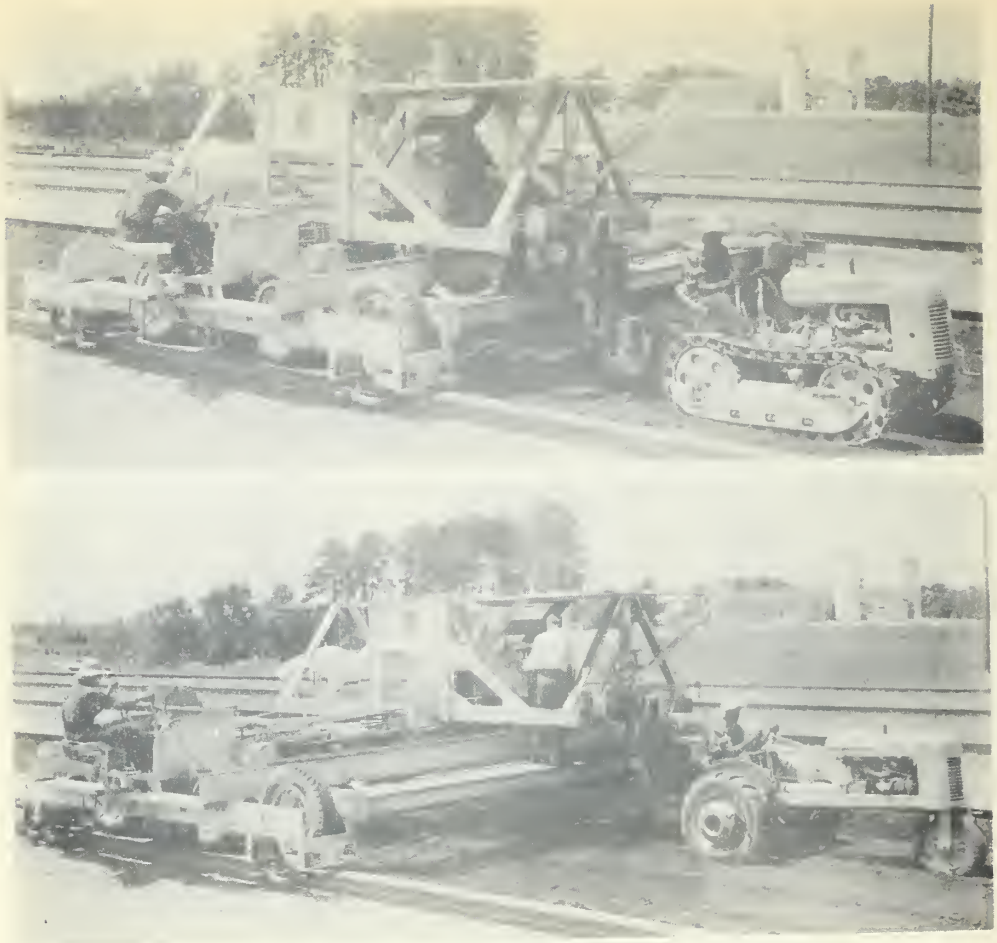

Fig. 3

Two Tractors Hitched to Power Car for Load as Used to Produce Impressions or Tracks.

Fig. 4

Impressions Produced in the Davidson Loam by the Tractors Shown in Figure 3.

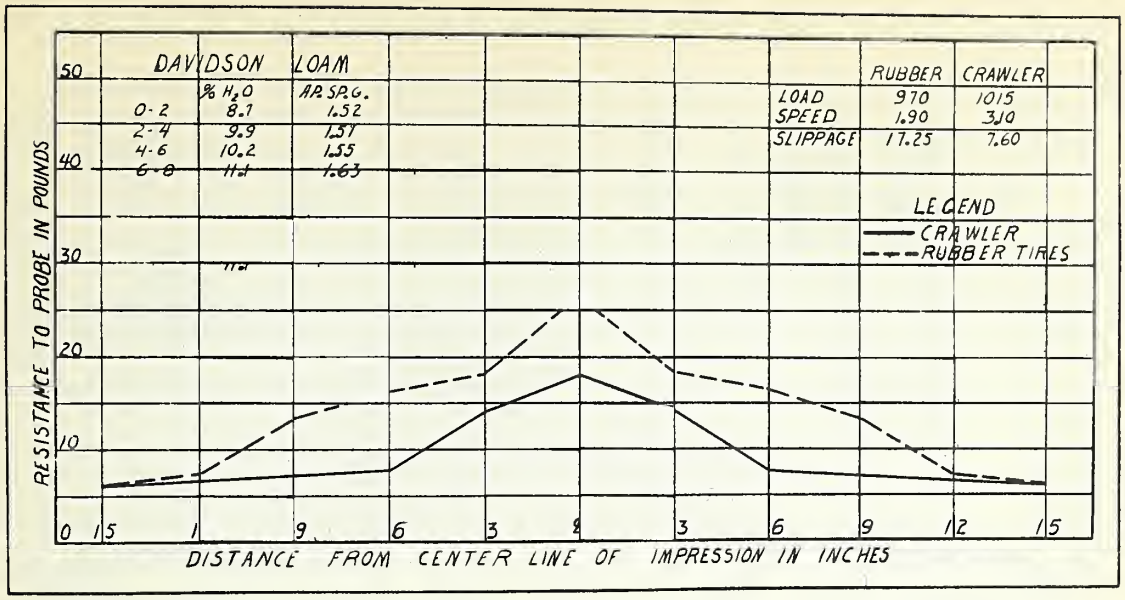

Fig. 5

Curves Comparing the Packing Effects of Steel Tires With 4-Inch Lugs and Pneumatic Tires in a Davidson Loam Soil.

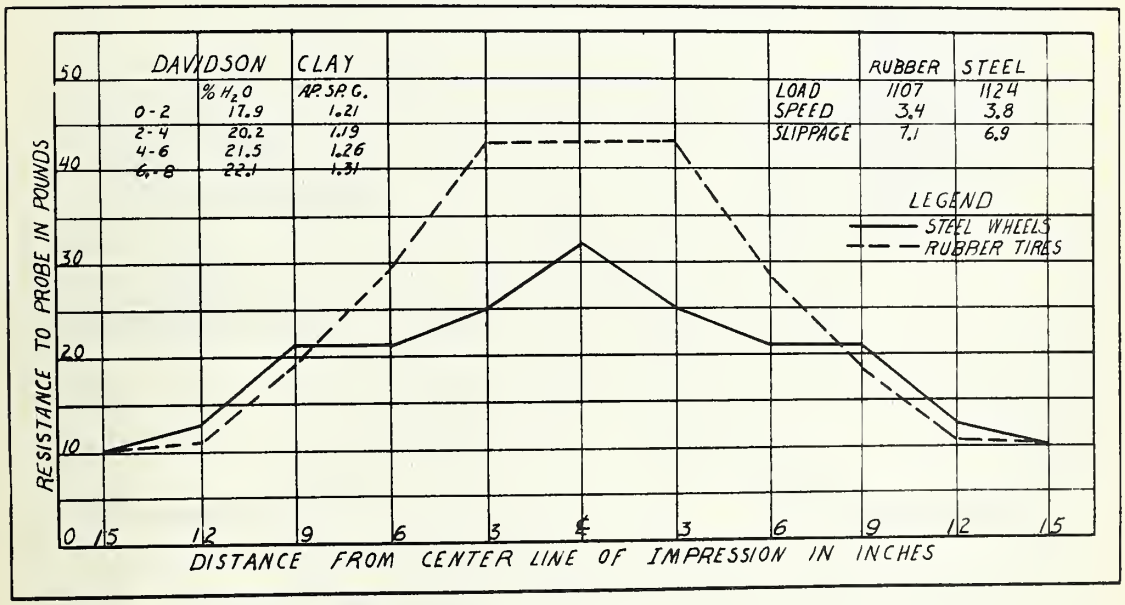

Fig. 6

Curves Comparing the Packing Effects of Steel Tires With 4-Inch Spade Lugs and Pneumatic Tires in a Davidson Clay Soil.

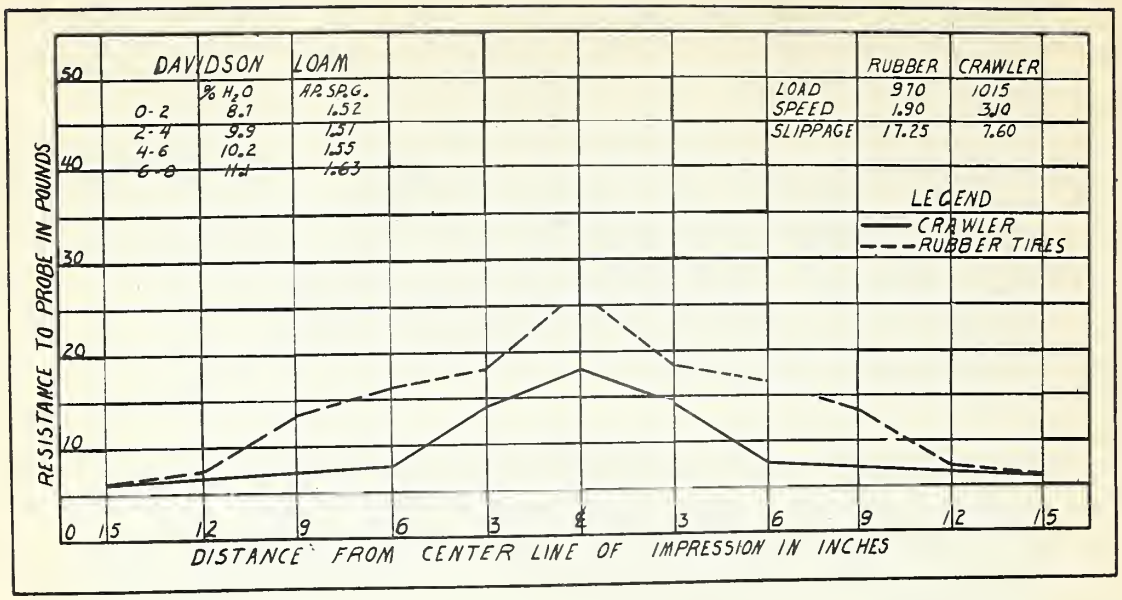

Fig. 7

Curves Comparing the Packing Effects of Crawler and Pneumatic Tire Equipped Tractors in a Davidson Loam Soil.

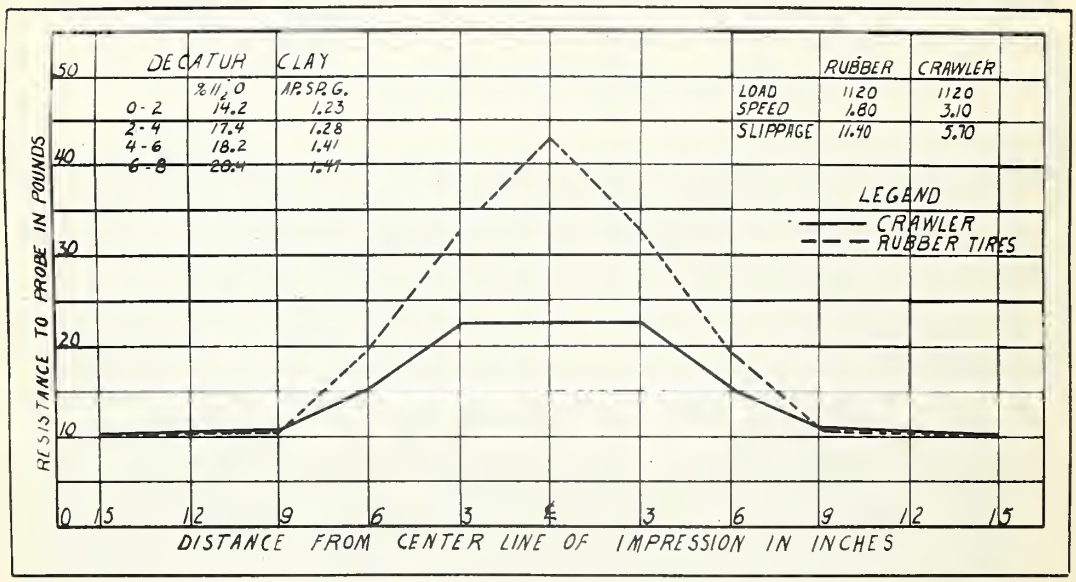

Fig. 8

Curves Comparing the Packing Effects of Crawler and Pneumatic Tire Equipped Tractor in a Decatur Clay Soil.